Evaluation of Digital Refractometers for Field Determination of FSII Concentration in JP-5 Fuel

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EXECUTIVE SUMMARY

Specification MIL-DTL-5624 requires the addition of Diethylene Glycol Monomethyl Ether (DiEGME) as a fuel system icing inhibitor at a concentration of 0.10 vol% to 0.15 vol% at the point of additive addition. During transport of JP-5 fuel from the point of additive injection to the point of use, additive loss is experienced to some degree resulting in additive concentrations frequently below 0.1 vol%. Navy field determination of the additive concentration is currently conducted using the American Society for Testing and Materials, ASTM D5006 referenced HB/B2 Analog refractometer. The HB/B2 refractometer has been in service for over 30 years and is a very precise instrument for DiEGME concentrations above 0.03 vol%. However, HB/B2 analog refractometer scale reading at the low DiEGME concentrations requires interpolation and is subjective. The ASTM D5006 method recently included digital refractometer instruments for DiEGME concentration determination. More precise measurements of DiEGME at low concentrations could be obtained by Navy field operators with the use of the digital refractometers.

NAVAIR successfully completed the evaluation of the digital refractometers and determined the ASTM Method D5006 referenced Gammon HB/2D Digital and the MISCO PA202 series digital refractometers are acceptable for Navy field determination of DiEGME fuel system icing inhibitor additive levels in Specification MIL-DTL-5624, JP-5 fuel.

LIST OF ACRONYMS/ABBREVIATIONS

American Society for Testing and Materials ..... ASTM

DiEthylene Glycol Monomethyl Ether ..... DiEGME

Fuel System Icing Inhibitor ..... FSII

Evaluation of Digital Refractometers for Field Determination of FSII Concentration in JP-5 Fuel

1.0 BACKGROUND

Fuel System Icing Inhibitor[1] (FSII) has been a required aviation fuel additive since 1971. FSII became a necessary fuel additive after several reports of ice formation causing fuel system malfunctions and downed aircraft. FSII is able to prevent the formation of ice by preferentially migrating to dissolved water and free water where it acts as antifreeze for the water. Since the 1980s Di-Ethylene Glycol Monomethyl Ether[2] (DiEGME) has served as the Navy's anti-icing additive. The Navy has established the minimum effective concentration of DiEGME at 0.03% by volume[3]. DiEGME is recommended for use in aircraft because of its secondary benefit of increased biostatic protection.

Due to DiEGME's solubility in water, DiEGME is often times lost through exposure to tanks that have not been sumped adequately or through drastic temperature changes which cause water dissolved in the fuel to come out of solution and settle at the bottom of the tank as free water. To offset these losses the Navy requires a larger DiEGME concentration in procured fuels. Originally, the Navy required a concentration of 0.15%-0.20% by volume DiEGME in all procured fuels. But due to lower than anticipated DiEGME losses during fuel transport, the current injection range has been lowered to 0.10%-0.15% DiEGME.

Research has been done to assess the feasibility of lowering the minimum required concentration of DiEGME even further. But before any real benefits can be drawn from reducing the allowable limits of DiEGME, a handheld refractometer that can accurately and precisely measure low levels of DiEGME must be identified. Current handheld analog refractometers are too subjective at lower concentration levels of DiEGME (≤0.03%) making it virtually impossible to definitively measure low concentrations of DiEGME in the field. An accurate digital refractometer would remove the subjectiveness associated with the current test equipment by providing a clearly displayed DiEGME concentration while also simplifying operation, and potentially reducing testing costs.

2.0 OBJECTIVE

The purpose of this study is to validate the ruggedness and accuracy of the latest models of the MISCO and Gammon digital refractometers compared to the current Navy approved B2 analog refractometer and determine the acceptability of these instruments for Navy field use. Unlike previous studies, this effort places emphasis on lower detection levels (≤0.05 vol% DiEGME).

3.0 APPROACH

A stock solution of 0.2 vol% DiEGME in JP-5 fuel was prepared. Aliquots of the stock solution were used to prepare the other additive concentrations. The sample dilution schedule is shown in Table 1. The DiEGME concentration of each of the prepared samples was verified in accordance with the ASTM Method D5006[4].

Table 1: Dilution Quantities Required to Produce Desired Concentrations

DiEGME Concentration, Vol%	Volume of 0.2% Solution Used	Volume of DiEGME Free Fuel Required
0	0	1000
0.0025	15	985
0.005	25	975
0.01	50	950
0.03	150	850
0.05	250	750
0.1	500	500
0.15	750	250
0.2	2600	0

4.0 DISCUSSION

4.1 General/Visual Assessment. Both the Gammon HB/2D digital refractometer and the MISCO PA202 digital refractometer were small, light weight, and sufficiently rugged for Navy field use. The power source for both instruments is standard AA Alkaline batteries. Battery change was not required for either unit during the evaluation which is a good indication of long battery life. The instruments operating instructions provided were complete and easy to follow. Both instruments were very simple in design and easy to operate. Values displayed in the digital displays were easy to read. The cleaning procedures are simple and require no detergents or chemicals.

4.2 Determination of DiEGME in JP-5 Fuel. The ASTM D5006 procedure was followed for determining the DiEGME concentration in the JP-5 test fuels. The test results are shown graphically in Figure 1. The raw data is contained in Appendix A, Table A-1. Test results were obtained in triplicate. The results obtained for the Gammon HB/2D digital refractometer and the MISCO PA202 digital refractometer were nearly identical and demonstrated exceptional accuracy and precision. Due to the limitations of the HB/B2 Analog refractometer, results below 0.03 vol% concentrations were displayed as 0.0 vol%. However, both digital refractometers were able to accurately determine the DiEGME concentration to about 0.003 vol% in JP-5 fuel. All test results obtained were within the established ASTM D5006 precision requirements. The precision data is contained in Appendix B.

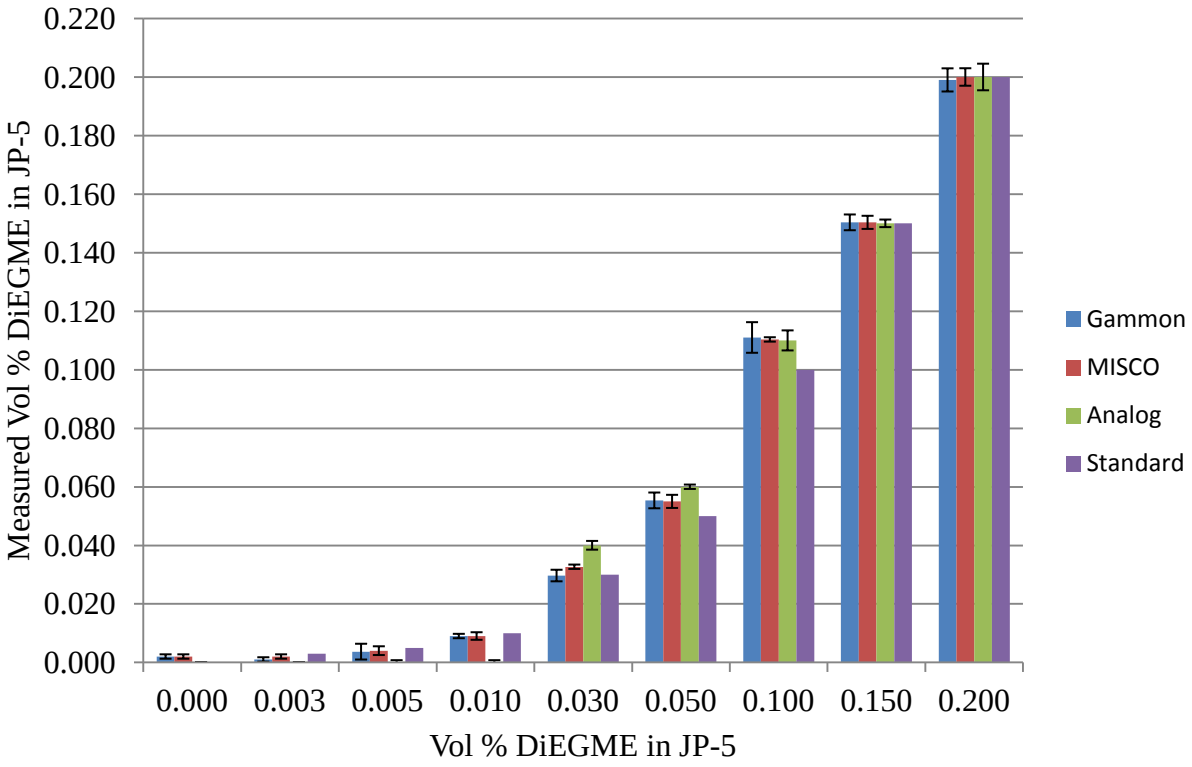

Figure 1: Refractometer Test Results

4.3 MISCO PA202X Similarity. Although the MISCO PA202X model was not included in this evaluation, contact with MISCO verified the PA202 and PA202X are comparable. The PA202X has the additional feature of a built in calibrated DiEGME scale. All other performance parameters are the same. Therefore, for qualification purposes, model PA202X shall be included.

5.0 CONCLUSIONS

1. The precision and accuracy of the Gammon HB/2D Digital Refractometer and the MISCO PA202/PA202X digital refractometers are equivalent to the B2 Analog refractometer.

2. The Gammon HB/2D digital refractometer and the MISCO PA202/PA202X digital refractometers are sufficiently rugged for Navy field use.

3. The Gammon HB/2D digital refractometer and the MISCO PA202/PA202X digital refractometers are acceptable instruments for Navy field determination of DiEGME additive concentrations in JP-5 fuel.

6.0 RECOMMENDATIONS

Revise the NAVAIR 00-80T-109 NATOPS Aircraft Refueling Manual and appropriate technical manuals and instructions to include the Gammon HB/2D digital refractometer and the MISCO PA202/PA202X digital refractometers for Navy field determination of DiEGME additive concentrations in JP-5 fuel.

7.0 REFERENCES

1. MIL-DTL-27686 – Inhibitor, Icing, Fuel System (superseded by MIL-DTL-85470)
2. MIL-DTL-85470 – Inhibitor, Icing, Fuel System, High Flash NATO Cold Number S-1745
3. NAVAIR 00-80T-109 – Aircraft Refueling Manual
4. ASTM D5006 - Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels

Table A-1: Refractometer Test Results

DiEGME Concentration by ASTM D5006 (Test Temperature 70°F)				
DiEGME Level In Fuel	**Trial #**	**vol% DiEGME**		
Standard		**Gammon**	**MISCO**	**HB/B2 Analog**
0.000 vol%	Trial 1	0.002	0.002	0.00
	Trial 2	0.002	0.002	0.00
	Trial 3	0.002	0.002	0.00
	Average	**0.002**	**0.002**	**0.00**
	Std Dev	**0.000**	**0.000**	**0.00**
0.0025 vol%	Trial 1	0.001	0.002	0.00
	Trial 2	0.001	0.002	0.00
	Trial 3	0.001	0.002	0.00
	Average	**0.001**	**0.002**	**0.00**
	Std Dev	**0.000**	**0.000**	**0.00**
0.005 vol%	Trial 1	0.004	0.004	0.00
	Trial 2	0.004	0.004	0.00
	Trial 3	0.003	0.004	0.00
	Average	**0.004**	**0.004**	**0.00**
	Std Dev	**0.001**	**0.000**	**0.00**
0.010 vol%	Trial 1	0.008	0.009	0.00
	Trial 2	0.011	0.009	0.00
	Trial 3	0.008	0.009	0.00
	Average	**0.009**	**0.009**	**0.00**
	Std Dev	**0.002**	**0.000**	**0.00**
0.030 vol%	Trial 1	0.029	0.032	0.04
	Trial 2	0.030	0.033	0.04
	Trial 3	0.030	0.033	0.04
	Average	**0.030**	**0.033**	**0.04**
	Std Dev	**0.001**	**0.001**	**0.00**
0.050 vol%	Trial 1	0.055	0.055	0.06
	Trial 2	0.055	0.055	0.06
	Trial 3	0.056	0.055	0.06
	Average	**0.055**	**0.055**	**0.06**
	Std Dev	**0.001**	**0.000**	**0.00**
0.100 vol%	Trial 1	0.110	0.110	0.11
	Trial 2	0.111	0.110	0.11
	Trial 3	0.112	0.111	0.11
	Average	**0.111**	**0.110**	**0.11**
	Std Dev	**0.001**	**0.000**	**0.00**
0.150 vol%	Trial 1	0.151	0.150	0.15
	Trial 2	0.150	0.151	0.15
	Trial 3	0.150	0.150	0.15
	Average	**0.150**	**0.150**	**0.15**
	Std Dev	**0.001**	**0.001**	**0.00**
0.200 vol%	Trial 1	0.199	0.200	0.20
	Trial 2	0.200	0.199	0.19
	Trial 3	0.199	0.200	0.20
	Average	**0.199**	**0.200**	**0.20**
	Std Dev	**0.001**	**0.001**	**0.01**

Precision

The precision of this test method as determined by statistical examination of interlaboratory results according to RR:D02-10075 is as follows:

1. *Repeatability*—

HB refractometer: repeatability 0.009 volume %
Brix scale refractometer: repeatability 0.005 volume %

2. *Reproducibility*—

HB refractometer: reproducibility 0.018 volume %
Brix scale refractometer: reproducibility 0.021 volume %

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14. ABSTRACT

Specification MIL-DTL-5624 requires the addition of Diethylene Glycol Monomethyl Ether (DiEGME) as a fuel system icing inhibitor at a concentration of 0.10 vol% to 0.15 vol% at the point of additive addition. During transport of JP-5 fuel from the point of additive injection to the point of use, additive loss is experienced to some degree resulting in additive concentrations frequently below 0.1 vol%. Navy field determination of the additive concentration is currently conducted using the American Society for Testing and Materials, ASTM D5006 referenced HB/B2 Analog refractometer. The HB/B2 refractometer has been in service for over 30 years and is a very precise instrument for DiEGME concentrations above 0.03 vol%. However, HB/B2 analog refractometer scale reading at the low DiEGME concentrations requires interpolation and is subjective. The ASTM D5006 method recently included digital refractometer instruments for DiEGME concentration determination. More precise measurements of DiEGME at low concentrations could be obtained by Navy field operators with the use of the digital refractometers. NAVAIR successfully completed the evaluation of the digital refractometers and determined the ASTM Method D5006 referenced Gammon HB/2D Digital and the MISCO PA202 series digital refractometers are acceptable for Navy field determination of DiEGME fuel system icing inhibitor additive levels in Specification MIL-DTL-5624, JP-5 fuel.

15. SUBJECT TERMS
Fuel System Icing Inhibitor, FSII, HB/B2 Refractometer, Digital Refractometer

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